GN-2899-01
Revised 15 Dec. 1971

FIELD PROCEDURE

FOR

COLOR COATING THE UNDERSIDE

OF LIFE RAFTS

19 NOVEMBER 1971

Approved For Release 2002/10/17 : CIA-RDP75B00285R000100090004-8

REVISION CHANGE LOG

REVISION NUMBER	AUTHORITY FOR CHANGE	DESCRIPTION OF CHANGE	AFFECTED PAGES	EFFECTIVITY
-01	Technical Correction	Spray Gun P/N From: GN9374P-04 To: GN9377P-04	2	-

INTRODUCTION

This field procedure is written for field technicians to provide instructions for color coating the underside of life rafts.

SPECIAL EQUIPMENT AND MATERIALS

Spray Gun	GN9377P-04
Cylinder, Power Unit (replaceable gas cylinder for spray gun)	GN9153P-12
*Coating, Fabric (Supplied in pints)	GN9990P-01HA000
Tape, Pressure Sensitive (120 yds. per roll)	GN9026P-19CG000
Solvent, Toluol (pints) (Thinner and cleaner)	GN9147P-0300000

*NOTE

Fabric coating has a limited shelf life. Above 70° F it may be stored for three months, but below 70° F it may be stored for six months. This material comes premixed and ready for use but it may be thinned with toluol if necessary.

1. Assemble spray gun using instructions enclosed with spray unit.

NOTE

Be sure that the power unit is fully seated up into the recess of the plastic headpiece as a misalignment of the power unit will direct the gas into the coating liquid rather then across the nozzle as intended.

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1. Assemble spray gun using instructions enclosed with spray unit.

NOTE

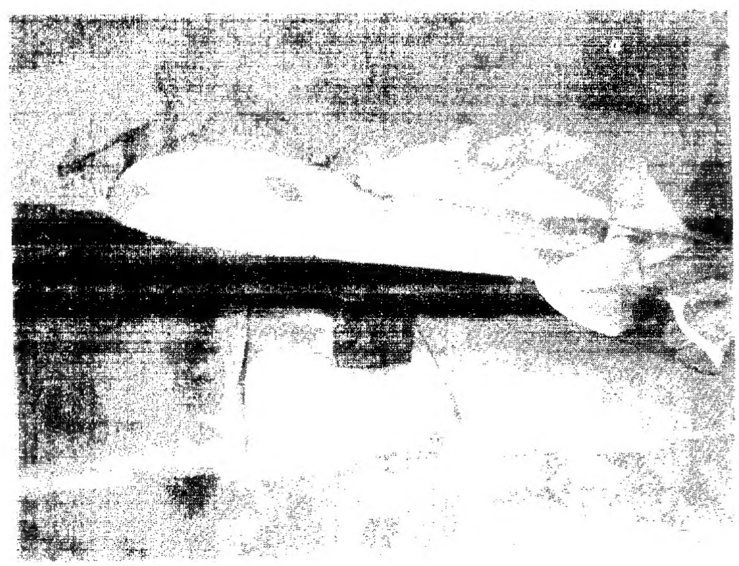
Be sure that the power unit is fully seated up into the recess of the plastic headpiece as a misalignment of the power unit will direct the gas into the coating liquid rather then across the nozzle as intended.

2. Inflate the life raft. Stuff paper (newspaper. kraft, etc.) into the ballast bags to keep them errect.
Mask the unit at the main cell outer center seam to avoid over spray on the upper portion of the raft. Use 2 inch wide masking tape and paper (newspaper, kraft, etc.).

STAT

3. Follow directions on spray unit, using fabric coating liquid GN9990P-01HA000. Spray with two light coats rather than one heavy one. Coat all unmasked areas on bottom of raft.

4. Dry raft under normal atmospheric conditions. Dries to touch in 20 to 30 minutes. Full cure effected in 10 hours.



5. Remove paper from ballast bags. Remove masking tape and paper from the main cell.

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Prediction of Tolerance in Cold Water and Life Raft Exposures

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HALL, J. F., JR. *Prediction of tolerance in cold water and life raft exposures.* Aerospace Med. 43(3):281-286, 1972.

A model based on net effective thermal insulation, assumed metabolism, surface area, and body mass is presented. The model permits prediction of tolerance time for clothed aircrewmen to attain specified limits (90, 125, 180 kcals) of body heat loss during: (a) cold water and (b) life raft exposures at various water or ambient air temperatures. The variables of hydrostatic compression, decreased insulation by wetting, and increased body cooling rate in water were considered and can be included in the tolerance predictions for water exposures. Factors of life raft air (I_a) and thermal insulation of a wet canopy type life raft are also included by assuming reasonable estimated values concerning air movement within the life raft and thermal insulation of the wet life raft respectively. Predictive tolerance curves based on net effective insulation and three body heat loss limits are presented for cold water and life raft exposures.

THE PROBLEM OF PROTECTING aircrews against cold water exposure due to emergency failures in aircraft or enemy action is a difficult one. Two aspects of this problem are especially demanding: (1) the development of practical effective protective clothing, equipment, or techniques which will provide adequate thermal protection and (2) development of suitable models or methods for providing valid predictive tolerance data useful in operational application for the safe rescue of aircrews exposed to cold water.

The severe physiologic strain imposed by cold water immersion has resulted in the development of both protective anti-exposure suits and insulated canopy type life rafts. Various concepts and practices applicable to the control of body heat loss from aircrews exposed to cold water or in life rafts have been described and experimentally explored.[2] The problems encountered in cold water exposure were admirably described and reviewed in the recent book by Keating.[9] The severity of cold water immersion as a physiologic stress, since the Dachau experiments as reported by Alexander[1] and in the reports of Glaser,[4] Wayburn,[14] Molnar,[10] and Veghte[13] has been clearly defined. The rapid body cooling and limited period of useful activity, particularly for exposed individuals not wearing protective clothing or only lightweight quickly wetted garments, was noted by Smith and Hames.[12] These authors also developed a nomogram for estimation of tolerance time in cold water based on the effects of the variables present in cold water immersion as these in turn affect mean body temperature. Mean body temperature was then related to a range of useful activity and survival time.

Biothermal research at the Aerospace Medical Research Laboratory during the period 1953-1968 included both physical and physiological investigations relating to the problems involved in cold water or life raft exposure.[5,6,7,8 and 11] These studies defined the roles of hydrostatic compression, wetting on thermal insulation, relative rates of body cooling in water as compared with air, metabolic effects, limits of mean skin, rectal, and body temperature associated with body heat loss limits of 90, 125, and 180 kcals, and thermal insulation values for the raft I_r (dry or wet) and raft ambient air (I_a raft). By using these factors, as applicable, for either the cold water or life raft exposure conditions, a predictive model was gradually developed.

The present paper attempts to present a predictive model useful for operational application in the rescue of cold water or life raft exposed aircrews. For Air Force operations the application of this data to life raft exposures is perhaps more realistic since, in most situations, this protective equipment should be available. However, in either the water immersion or life raft exposure the limiting amounts of body heat loss selected (90, 125, and 180 kcals) are all considered within safe human tolerance limits. The body loss limits of 90, 125, and 180 kcals correspond in general terms (based on extensive literature reports and this Laboratory's data) to mild, moderate, and severe degrees of body cooling respectively. The mean body temperature associated with the most severe (180 kcals) body heat loss limit in this model is 32.8°C. This value is in close agreement with

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the 33°C body temperature lower limit for useful activity as proposed by Smith and Hames.[12]

METHODS AND RESULTS

While previous investigators[1,11,and12] have defined survival ranges or limits in general terms, predictive data concerning safe tolerance times for aircrews exposed to cold water, directly or when in life rafts, have not previously been generally available. The various factors investigated and considered in the present model for predicting human tolerance to cold water immersion or during life raft exposures are examined in detail in the following discussion.

Calculation of Predicted Tolerance

A. *Cold Water*—The following equations and methods were used for calculating body heat loss at various water temperatures:

Heat Loss Through Clothing $(-Q)$

$$= \frac{3.09(\overline{T}_s - T_w)\,SA}{I_g} = \text{kcals/hr}$$

where $\overline{T}_s$ = Mean Skin Temperature—°F
T_w = Water Temperature—°F
SA = Surface Area (1.8 M^2)
I_g = Net Effective Body Insulation Worn

Net Heat Loss = $(-Q) + 100$ kcals/hr ($H_r + H_c$ body heat transfer for metabolism of 75 kcals/M^2 hr)

Tolerance Time in Water

$$\frac{90/\ 125/\ 180}{\text{Net Heat Loss}} \times 60/2 = \text{Tolerance Time (minutes)}$$

B. *Life Raft*

Heat Loss Through Clothing and Life Raft $(-Q_1)$

$$= \frac{3.09(T_s - T_a)\,SA}{I_g + (I_{raft} + I_{a\ raft})} = \text{kcals/hr}$$

where T_s = Mean Skin Temperature—°F
T_a = Ambient Air Temperature—°F
SA = Surface Area (1.8 M^2)
I_g = Net Effective Body Insulation Worn
I_{raft} = Insulation of Wet Raft
$I_{a\ raft}$ = Insulation of Raft Air

Net Heat Loss = $(-Q_1) + 100$ kcals/hr ($H_r + H_c$ body heat transfer for metabolism of 75 kcals/M^2 hr)

$$\frac{90/\ 125/\ 180}{\text{Net Heat Loss}} \times 60 = \text{Tolerance Time (minutes)}$$

TABLE I. RELATIONSHIP OF MEAN SKIN ($\overline{T}_s$), RECTAL (T_r), AND BODY (T_b) TEMPERATURE TO SELECTED HEAT LOSS TOLERANCE LIMITS

HEAT LOSS LIMIT (kcals)	90	125	180
$\overline{T}_s$ – °C	31.1°	30.0°	28.3°
($\overline{T}_s$ – °F	88°	86°	83°)
T_r	35.9°	35.6°	34.7°
T_b	34.2°	33.6°	32.8°

Water Immersion Exposures

The extent of mean skin and extremity cooling of clothed subjects, purposely maintained with dry insulation during cold water immersion, was first investigated[5] and insulative requirements for both the body and extremity (hand) noted. Percentage metabolic increases in cold water immersion, as related to the thermal insulation covering the body, was also measured. While this study yielded useful basic data on mean foot, hand, and skin temperature, cooling rates, and acceptable limits of body heat loss, it emphasized strongly the importance of the following factors: (1) decrease in thermal insulation due to hydrostatic compression, (2) decrease in thermal insulation due to wetting, and (3) increased rate of cooling for the clothed immersed subject (wearing wet or dry clothing) in water. With respect to the present model, each of these factors was investigated and is discussed below:

(1) Decrease in thermal insulation (I_g) due to hydrostatic compression: With the subject completely immersed except for head-neck areas, most (92%) of the body area is subject to hydrostatic compression and consequent reduction of thickness. When measured with the thermal (copper) manikin technique, this reduction was 46% with the specific assembly measured. However, with more compression resistant clothing, this reduction would be significantly less. For the model curves presented, a mean reduction of 25% in thermal insulation due to hydrostatic compression was assumed and used. By use of the thermal manikin techniques, the actual reduction due to hydrostatic compression of any specific assembly can be precisely determined.

(2) Decrease in thermal insulation (I_g) by wetting: Water due to leakage into the clothing assembly, sweat accumulation, or both results in a decrease also in thermal insulation. With the maximum water content measured (1051 gms/M^2), the thermal insulation loss[6] amounted to 50%. This degree of wetness closely approximates a saturation degree of wetness. By determining the amount of wetting occurring in a given specific protective assembly, the percentage reduction of thermal insulation can then be closely estimated (or by use of thermal manikin techniques actually measured). In the model curves presented, this determination then permits the selection of the appropriate net effective insulation predictive tolerance curve.

(3) Increased rate of cooling of the clothed aircrew member in water: Experiments were previously conducted with the thermal (copper) manikin technique[6] to determine the relative heat loss rate (or rates) in water as compared with air. In these experiments, the entire body (except the head-neck area), including the extremities, was immersed in the cold water. These experiments demonstrated this ratio to vary between 2.3 and 4.0 depending upon whether or not clothing was dry or maximally wetted. For a precise value for the water cooling rate, the amount of clothing wetness, of course, should be determined in any specific protective assembly. However, since the more recent anti-exposure suits (CWU-21/p) are designed to function as a dry suit, the lower ratio value, (2) was used in the net effective insulation curves presented in the present model.

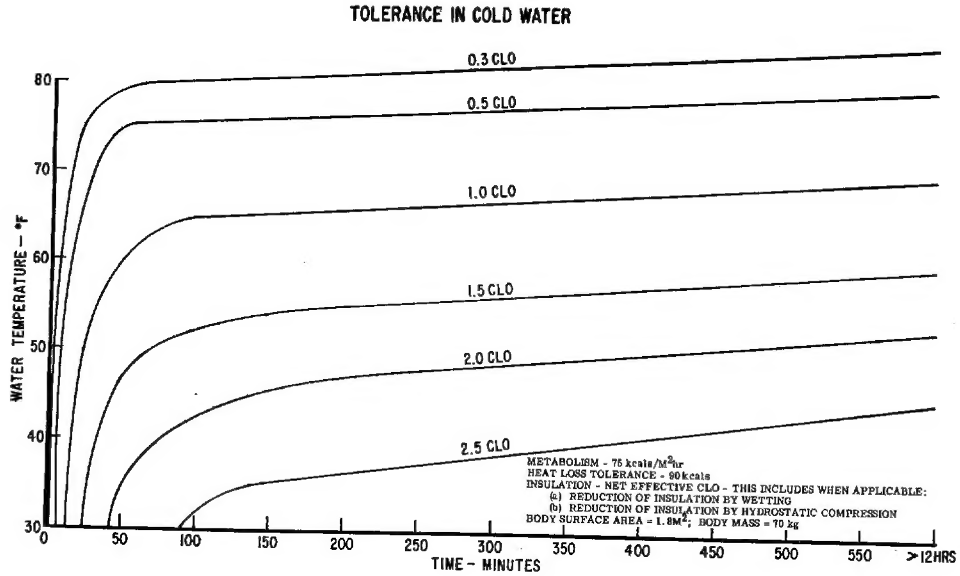

Fig. 1. Net effective insulation and tolerance in cold water—90 kcals limit.

Life Raft Exposures

In comparison with the cold water exposures, the thermal stress and consequent physiologic strain is, in general, significantly reduced in life raft exposures. For thermal protection against cold water exposure, the standard Air Force procedure includes as rapid an entrance as possible by the exposed crew members to an insulated canopy type (LRU-6/p) life raft. In the model presented, entrance to such a life raft within five minutes by the personnel trained in survival and a wet life raft interior was assumed.[7,8]

Comparison of life raft versus the cold water immersion exposure shows the following significant changes in the factors, eventually increasing raft tolerance time: (1) hydrostatic compression is lacking, thus, a gain in thermal insulation is achieved, (2) entrance to the wet raft results in a net effective thermal insulation gain (approximately 1.2 clo), (3) body cooling is slower in life raft (air) cooling than in immersion (water) exposures.

(1) Hydrostatic compression factor: The loss due to this factor in cold water immersion,[6] which may range from 10 to 50% depending upon compression resistance of the clothing worn, is regained. In the model presented, a mean value of 25% regain was used.

(2) Net effective insulation gain by entrance to the raft: Previous measurements using the thermal (copper) manikin technique[8] indicated a value of 1.0 clo as the insulation (I_{raft}) for the type raft specified. An estimated reduction of 30% due to wetting was included in the present model, and it was assumed that the mean air movement within the raft results in a thermal insulation of 0.5 clo.

(3) Body cooling during the raft exposure occurs essentially in an air medium rather than water and is significantly slower.[6] A rate minimally only one-half that observed in water cooling was observed and is used in the present model.

Predictive Tolerance Curves

In Figures 1, 2 and 3, the predicted tolerance curves are presented for the crew members immersed in cold water to reach specified limits of body heat loss when exposed to various water temperatures and when wearing various amounts of clothing (expressed as net effective insulation). In Figures 4, 5, and 6, similar predicted tolerances for the raft exposed crew member exposed to various ambient air temperatures and wearing various net effective insulations are graphed.

In application of the cold water curves, the degree, if any, of wetting, of course, should be known or estimated as accurately as possible to determine the appropriate net effective insulation to use. In the life raft applications, it should be emphasized that the curves presented, while showing body insulation worn, also include the value, 1.2 clo, which represents the life raft insulation (0.7) and life raft ambient air insulation (0.5).

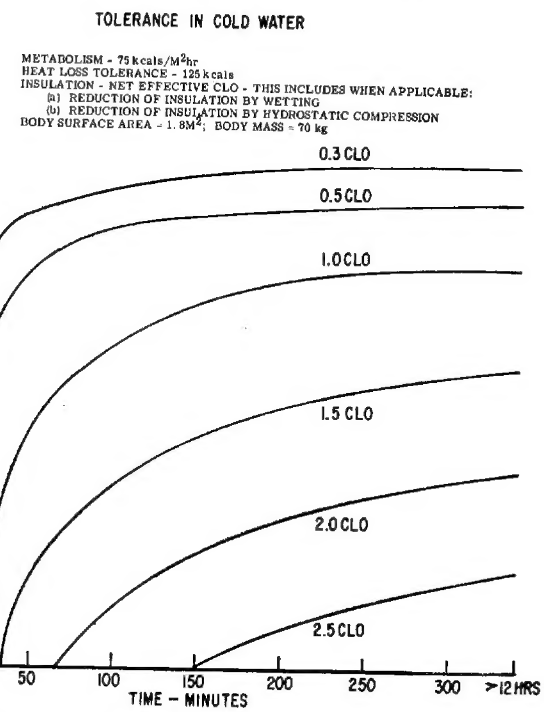

Fig. 2. Net effective insulation and tolerance in cold water—125 kcals limit.

DISCUSSION

The model presented attempts, on the basis of net effective thermal insulation and several assumed limits to body heat loss, to provide a useful predictive method suitable for application to Air Force operational rescue missions. The model may also provide helpful guidelines for design of more adequate thermal protective clothing especially applicable to cold immersion or life raft exposures.

As in any predictive model, there exists a number of areas where difficulties exist and assumptions represent some compromises. Among these problem areas, the following should be discussed:

(1) Disparate rates of cooling in cold water exposure occur since the head-neck area is air cooled in contrast to the water cooled body. In the model, the entire body was treated as water cooled. The practical difficulties of wearing head insulation equivalent to body insulation and of retaining headgear during the parachute and water entrance phases of emergency cold water exposure should be mentioned. The critical importance of head insulation in cold air exposure has been clearly demonstrated.[3]

(2) Extremity cooling, especially in cold water immersion, is a critical factor since rapid cooling and the

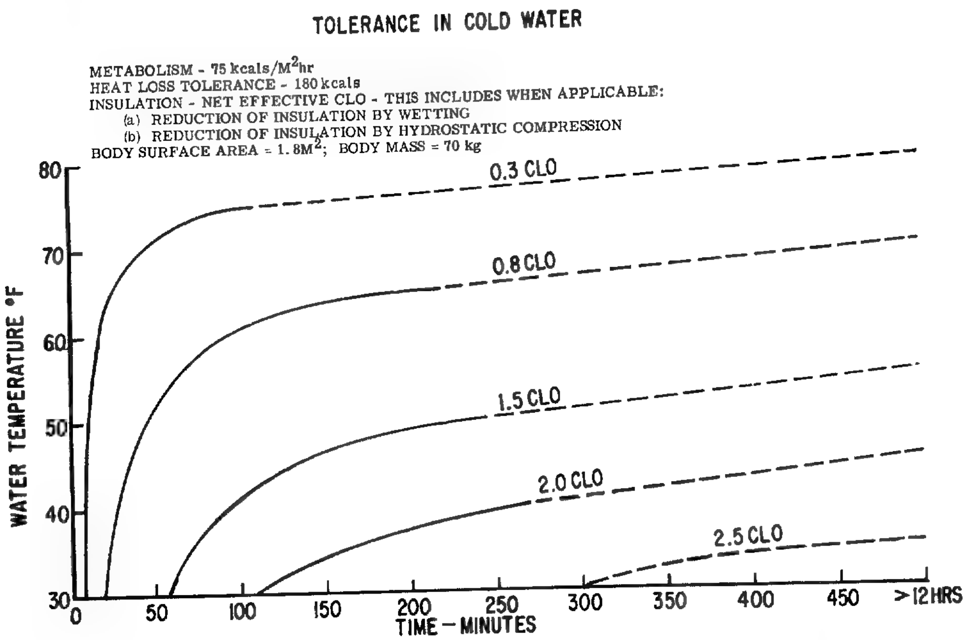

Fig. 3. Net effective insulation and tolerance in cold water—180 kcals limit.

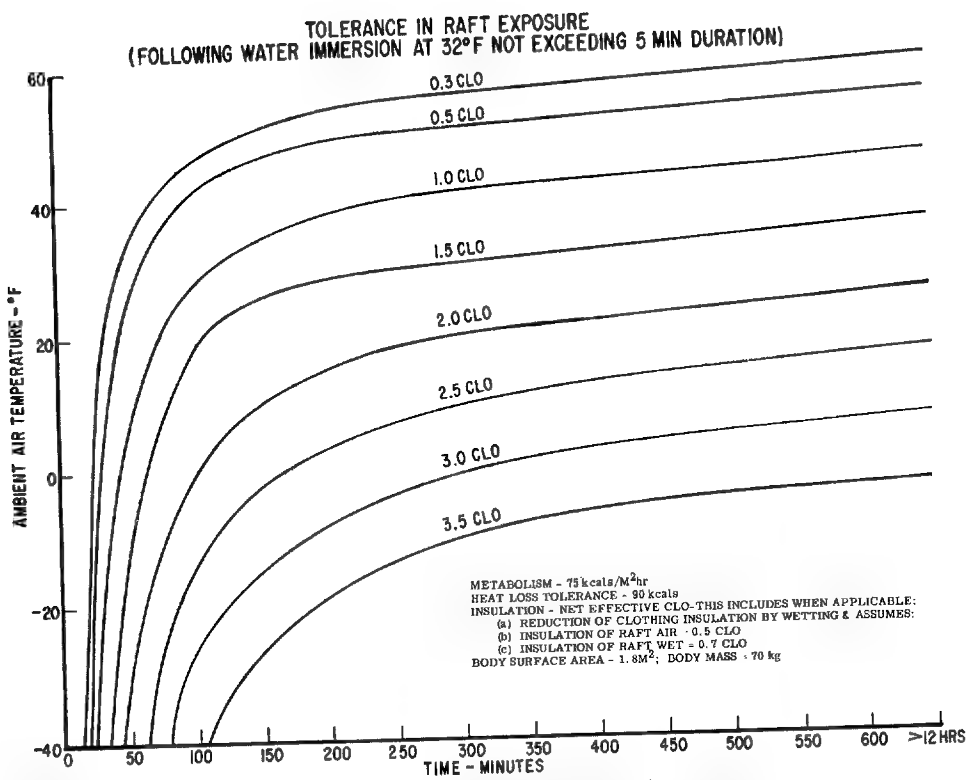

Fig. 4. Net effective insulation and tolerance in life raft exposure —90 kcals limit.

fact that thermal insulations covering these areas, sensitive on a vasomotor basis, are seldom equivalent to that covering the body (arms, legs, trunk). In the present model, extremity insulation was assumed equivalent to body insulation.

(3) Increased metabolism due to shivering is, of course, one mechanism for increasing heat production in cold water or life raft exposures. However, extreme individual variability in threshold, intensity, and ability to maintain a high metabolic level are complicating factors here. It was, therefore, considered a reasonable compromise to assume a moderate and constant metabolic rate (75 kcals/M^2hr).

(4) In life raft exposures a disparate type heat loss also occurs since a variable fraction of the wet raft occupant's body area (thigh, buttocks, and feet) is exposed to water cooling rather than air cooling. However, for the model prediction of life raft tolerance, the entire body area was assumed to be air cooled. Treatment of this complex heat loss problem by application of the Air Force biothermal analog computer techniques is planned.*

*At the University of Washington, Department of Physiology and Biophysics, Seattle, Washington, under Contract AF33515 69-C-1306.

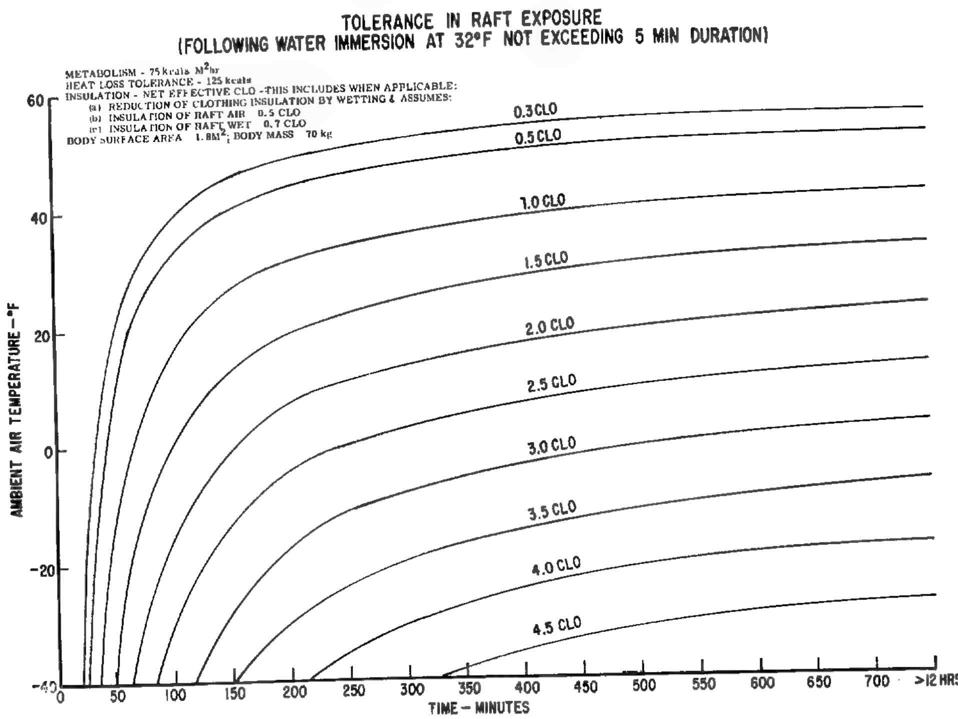

Fig. 6. Net effective insulation and tolerance in life raft exposure —180 kcals limit.

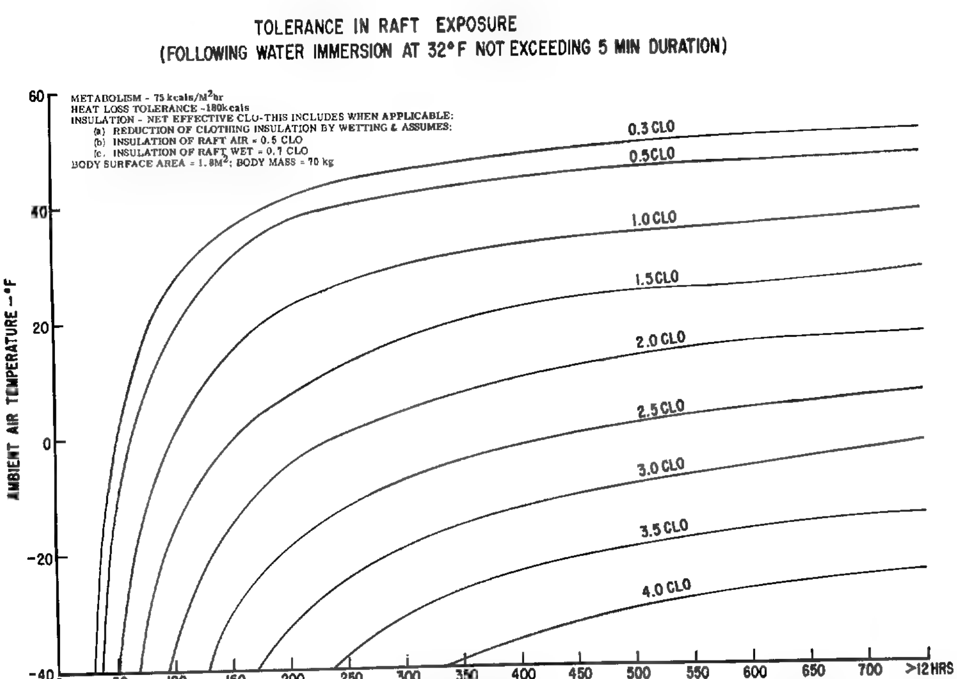

Fig. 5. Net effective insulation and tolerance in life raft exposure —125 kcals limit.

(5) The factors of mass (70 kg) and surface area (1.8 M^2 assumed represent those of an average individual. Some differences in actual tolerance time as compared with predicted tolerance time may thus occur with crew members who vary markedly from the average values. These extreme cases, however, represent a relatively small percentage of total population and with many other factors (metabolic level, vasomotor sensitivity, physical fitness, and cardiovascular efficiency) also playing variable roles, it was thus considered most useful to base heat loss limits on average mass and surface area.

(6) The model presents predictive tolerance time to attain specific limits of body heat loss. It does not attempt to predict "survival" time, which is an entirely different concept and itself subject to the influence of many variables in addition to those treated by this model. The body temperature (32.8°C) represented by the model's most severe body heat loss (180 kcals) agrees closely with the lower limit of body temperature associated with "useful activity" as proposed by Smith and Hames.[12] These authors' nomographic treatment, however, for estimating tolerance time in cold water fails, however, to (a) provide precise tolerance time data, or (b) include life raft exposure predictions.

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G-suit Control of Massive Bleeding

The application of external counterpressure by means of a G-suit temporarily controls intraperitoneal and lower extremity hemorrhage secondary to massive trauma. The suit thus buys time while blood is being replaced and the injured patient is being transported to a facility where definitive surgical hemostasis can be achieved. Application of compression below the diaphragm apparently increases arterial resistance and causes venous blood to be translocated centrally away from that portion of the body being compressed to allow more adequate perfusion to the head and heart. Before use of the G-suit, patients brought to a medical clearing company in Vietnam for resuscitation from severe hypotension caused by massive blood loss secondary to acute trauma invariably died en route to the surgical hospital located forty-five minutes away by helicopter. After the G-suit was put into use, 7 of 8 acutely traumatized patients were successfully evacuated and 4 of the 8 survived.

Bruce S. Cutler, M.D., Massachusetts General Hospital, and Willard M. Daggett, M.D., Massachusetts General Hospital and Harvard University, Boston. Application of the "G-suit" to the control of hemorrhage in massive trauma. *Ann. Surg. 173:511-514, 1971.* For reprint: Dr. Daggett, Massachusetts General Hospital, Boston, Massachusetts 02114.

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Cold Sea Survival

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Two prototype three-man life rafts were evaluated during the winter months in Arctic waters off Kodiac Island, Alaska, to assess potential survival problems and determine tolerance limits. Each raft incorporated thermal characteristics specifically designed for cold water. Water and air temperatures varied from 0 to +2 C and −5 to +4 C respectively. Surface and core temperatures of each of the three subjects were monitored continuously during the 22-hour exposure in the TUL raft and the 6-hour exposure in the P-B raft. Each subject wore a different clothing assembly: a full pressure suit, light flight clothing, and the ventile anti-exposure suit. All subjects were removed upon reaching subjective tolerance. The results showed that none of the clothing assemblies was adequate to maintain a person in comfort even with dry boarding. No significant biochemical shifts in the blood or urine were found. The TUL raft was found to be superior in its thermal characteristics and afforded better subject protection. General tolerance for cold water immersion, wet and dry, and cold water raft exposures are depicted graphically, based on previously reported data.

EXPOSURE TO COOL WATER or cold air is a common experience, and the healthy person is able to tolerate considerable temperature changes in his environment without harm. Immersion in cold water, however, represents an extreme circumstance and, without protection, the resultant heat loss is precipitous. The sinking of the Titanic in 1912 provides a dramatic example, in that not one of the 1,489 persons immersed in the 0C water was alive when rescue vessels arrived one hour and fifty minutes after sinking, whereas almost all the people in boats were alive.[25] Because of the number of deaths attributed annually to this stress, an appreciable amount of research is continually conducted in this area. The capability of persons to withstand cold water immersion is well documented and many considerations are known that temper interpretation of tolerance data.

Natural body insulation, for example, is extremely important and fat men show less rise in metabolic rates than thin men during prolonged exposure to cold air.[38] Later these data were supported in cold water immersion studies and a linear relationship was found between change in core temperature and the thickness of subcutaneous fat.[7,19]

Another factor is the increased metabolic heat losses in lightly clothed subjects.[19] Experimental results with cold water survival equipment are not as clearly defined as nude studies, but based on experience in the Arctic, exercise is not a recommended regimen during prolonged exposures because of greater heat losses.

Another important factor to consider is the loss of tactile discrimination that occurs very rapidly (<1 minute) with total body immersion in cold water (0C). This loss makes it exceedingly difficult to board a life raft. Finger skin temperatures drop close to water temperatures in a remarkably short time. While in the raft, the Lewis effect (cyclic changes in peripheral blood flow) may or may not occur.[9,11,15]

Until recently the sudden deaths that occurred a few minutes after cold water immersion were attributed to hypothermia. Keatinge has conducted a number of studies in this area which have provided more insight into this problem.[18] Based on these test results, it has been postulated that, with a few individuals, death in cold water may be caused by respiratory difficulty as a result of the reflex input from cutaneous cold receptors. These events cannot be medically determined before the exposure and may occur in healthy, strong swimmers. Disturbances in the cardiac rhythm and extrasystoles are also seen in some swimmers upon sudden immersion in cold water.

The purpose of this study was to assess physiologic problems associated with cold sea survival. Because of the large number of studies in this area, a comprehensive library search was done to determine the tolerance limits for total body cold water immersion, both wet and dry, and raft exposures. This search quickly revealed that, besides the so-called tolerance times and subjective comments, almost no physiologic data have been obtained outside of the laboratory. Therefore, a field study was conducted off Kodiak Island, Alaska, during the winter months to obtain such data.

MATERIALS AND METHODS

Three volunteer test subjects participated in this study. All were experienced thermal test subjects in good physical condition, well motivated and thoroughly indoctrinated in cold water immersion problems. Table I lists various anthropometric data for each subject.

The test subjects and four experimental monitors were transported in a U.S. Navy YTM harbor tug to the test site approximately one mile offshore. The subjects were then dressed, control skin (17 different sites) and core temperatures were taken with portable Yellow Springs Telethermometers.[34] The weighted skin tem-

peratures (T_s) were obtained using the DuBois coefficients, and the mean body temperatures (T_b) were determined by the Burton formula, 0.67 T_r (rectal) + 0.33 T_s (mean skin). The tympanic thermometer and various thermistors recorded physiological and physical data (Figure 1). Water temperature was recorded with a thermistor or mercury thermometer and wind velocity monitored by a vane anemometer; wave height was assessed subjectively.

Each subject was hoisted overboard by means of a boom and guided into the designated raft position by a pararescue monitor. The rafts were boarded without water spillage and all subjects remained dry. This procedure was followed to avoid the variability induced by insulative losses because of wet clothing. The subjects then "buttoned up" the raft, and as soon as the instruments were checked, the raft was released from the side of the tug and allowed to drift freely away to the end of the 40-foot tether line. The personal leads were affixed to the tether line secured to the stern. A portable lighting system and a hard wire voice intercom system were provided for each raft. The experiment was to be terminated: (1) if rectal temperature (Tr) reached 35.0 C, (2) at the subject's request, (3) at the discretion of a standby medical monitor, (4) in the event of severe weather conditions, or (5) if any skin temperature (Ts) reached 0C and remained there for 2 minutes.

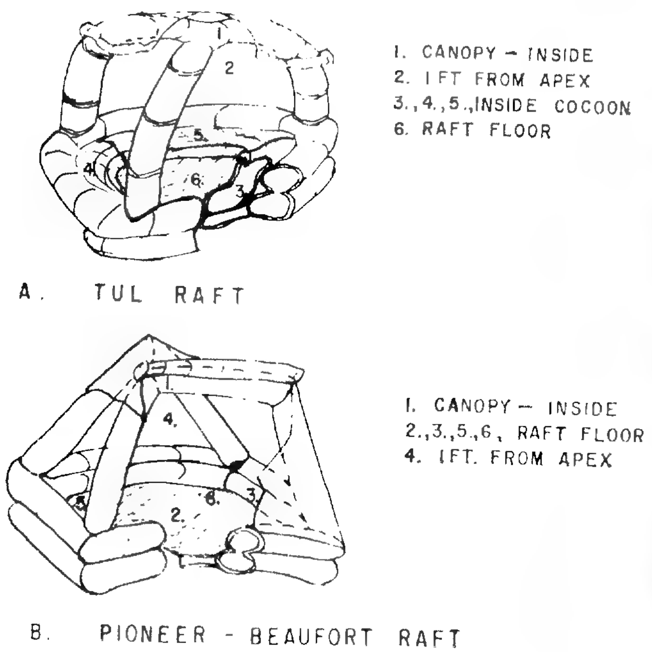

Fig. 1. Position of thermistors in rafts.

In addition various biochemical tests were performed before and immediately after the TUL raft exposure. These tests were performed by a competent hospital corpsman in the dispensary located at Kodiak Naval Station. The urine protein and sugar readings were determined by means of Combistix strips. The hematocrit (HCT) and hemoglobin (HGB) were obtained by standard centrifuge methods and the cyanmethemoglobin technique respectively.

Two prototype three-man rafts that incorporated unique thermal characteristics specifically designed for cold waters were procured from commercial sources (Figures 2 and 3). The first raft to be evaluated was the

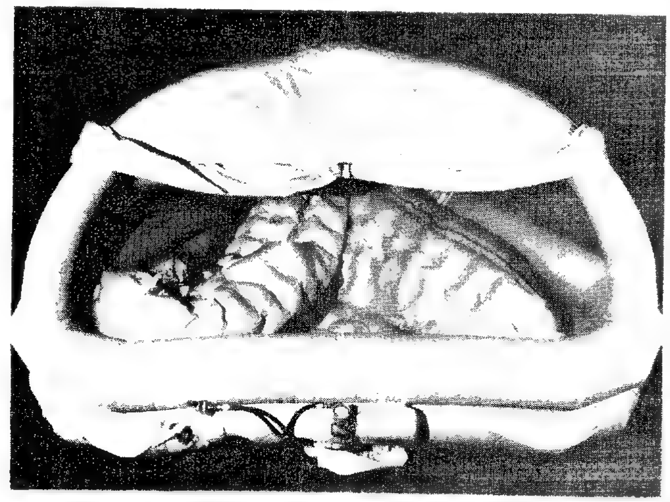

Fig. 2. TUL Life Raft.

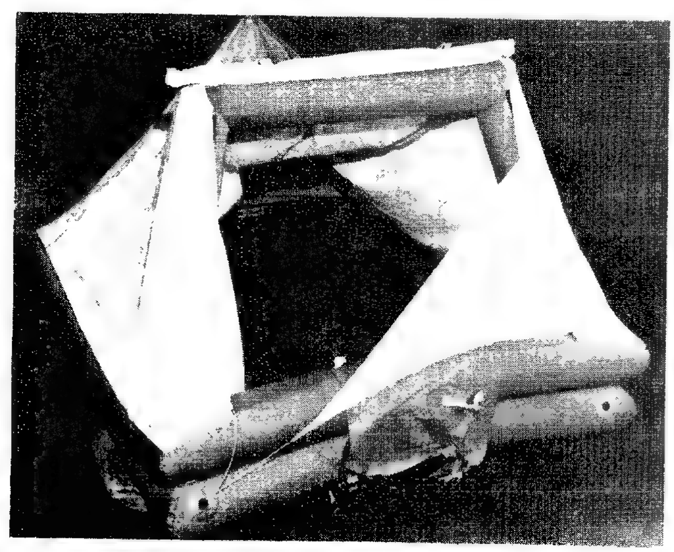

Fig. 3. Pioneer-Beaufort Life Raft.

TABLE I. ANTHROPOMETRIC DATA
Skinfold Thickness (mm) Body Region

	Age (Yr)	Hgt (cm)	Wgt (kg)	Sub Scapula	Triceps	Juxta Nipple	Supra Iliac	Mid Axillary Line Xyphoid Process	% Fat Total Body Weight
Subject A	31	177.8	72.7	9.2	7.0	8.0	9.5	6.6	11.9
B	32	170.2	74.5	12.7	6.9	16.5	14.6	9.3	14.2
C	27	167.6	68.2	6.1	7.4	5.9	8.5	8.0	12.1

Each subject wore a different clothing assembly (Table II)

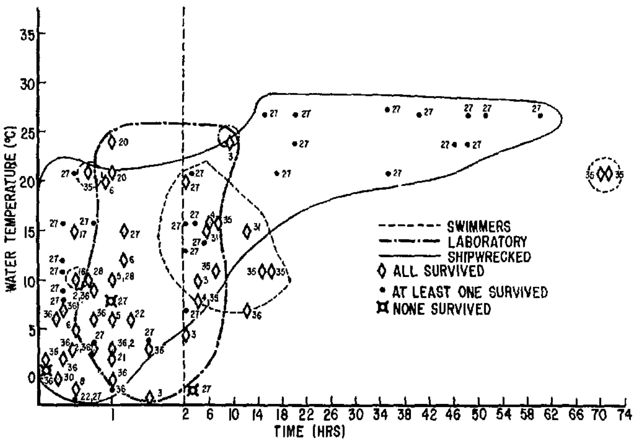

Fig. 4. Tolerance time at different water temperatures for total body immersion-wet. This illustration shows a plot of the actual data points. The numbers refer to the numbered reference citation.

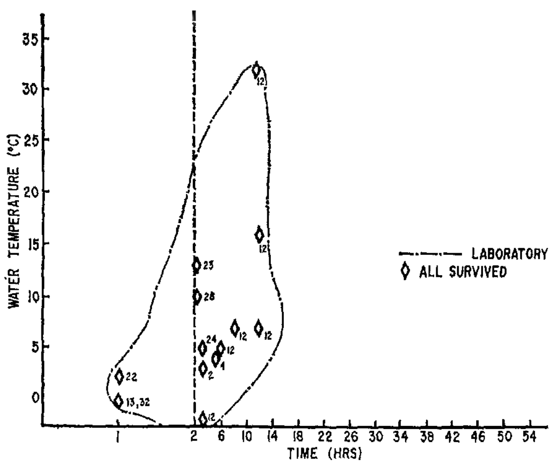

Fig. 5. Tolerance time at different water temperatures for total body immersion-dry. This illustration shows the data points of experiments in which the subjects wore impermeable cold water survival equipment. The only existing data pertains to laboratory experiments.

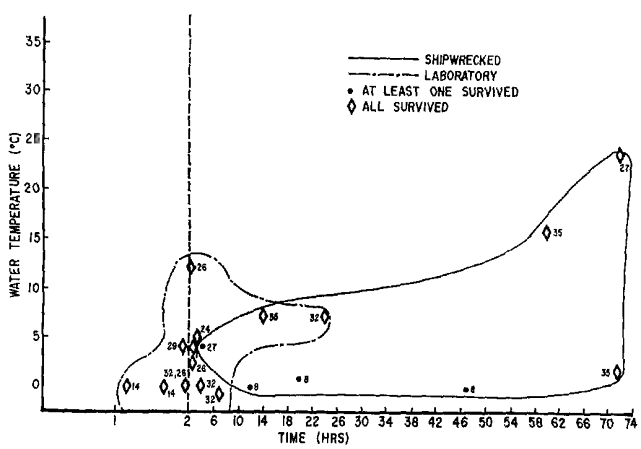

Fig. 6. Tolerance time for different water temperatures while in life rafts. This illustration depicts the available data on tolerance times of persons in life rafts in cold water.

TUL Raft, which had an individual inflatable cocoon for each subject. The second, P-B Raft, was tested as long as the subjects could tolerate the cold, based on their physiological status following the first test.

RESULTS

Figures 4, 5 and 6 depict tolerance times reported in the literature. Previously all data had been lumped and shown in the same figure. It became apparent that the data should be divided into three types of exposures: swimmers, persons who were shipwrecked, and laboratory test subjects. The data were also coded according to survival rate. The most severe exposures, in terms of duration and water temperatures, were found in persons who had been shipwrecked. The numbers beside the data points pertain to the reference source.

Figure 4 illustrates tolerance times reported in the literature for persons submersed in cold water wearing only light, water permeable clothing.

The outlined envelopes readily show that persons are not able to tolerate 0C water exposures for more than 90 minutes. At the warmer water temperatures increased tolerance times are encountered but tolerance times are still less than 18 hours for water temperatures as warm as 12 C. One is forced to reach the conclusion that unprotected lightly clothed persons will survive for only a few hours in Arctic waters (water temperature. Tw <5 C).

Figure 5 illustrates tolerance times for persons in cold water protected by immersion suits. Only laboratory results are available, and as a result, only relatively short time exposures were used. Tolerance times under these conditions are enhanced by this clothing, but it is impossible to predict survival times.

Figure 6 provides more useful data in terms of this study for long duration exposures. The increased buffer provided by the raft between the cold water and the man extended tolerance times for a period of days.

In the field test individual skin and core temperature changes during the exposures are plotted in Figures 7, 8, and 9. In the TUL raft exposure tympanic temperature recordings were not taken during the night because of the subjects' discomfort and their need for sleep. Rec-

TABLE II. TEST CLOTHING ASSEMBLIES

Subject A—*NASA Flight Clothing.* Thermistor underwear, two-piece waffle-weave underwear, two-piece NASA flight coveralls (jacket BW-1060-002, trousers BW-1061-001), boot assembly (BW-1062-002), one pair light cotton socks, one pair wool cushion-sole socks, wool inserts and leather gloves, wool cap, underarm life vest kit (SEB-40-100165-20). Clo value est. 1.5 clo.

Subject B—*Air Force Anti-Exposure Assembly.* Thermistor underwear, two-piece waffle-weave underwear, Batted anti-exposure suit liner, ventile exposure suit (AF first article), 5 ozs. Nomex winter flight coverall, one pair medium athletic socks, one pair heavy wool socks, leather flight boots, CNU-10/P gloves, CNU-ventile hood. Underarm life vest kit (SEB-40-100165-20). Clo value est. 2.0 to 2.5 clo (Unpublished data, AMRL).

Subject C—*NASA Full Pressure Suit.* (Fitted by NASA personnel). Thermistor underwear, full pressure suit (Gemini EVA suit with gloves but without helmet), neck barrier, one pair light cotton socks, one pair heavy cotton socks, one pair nylon gloves, one Air Force pile cap. Underarm life vest kit (SEB-40-100165-20). Clo value 1.7 to 2.0 clo (10).

tal temperatures dropped rapidly from initial values to 36 C during the first few hours as the subject's thermal condition equilibrated. The core temperatures of the subjects in the NASA flight clothing and the AF ventile exposure assembly oscillated throughout the remainder of the test period at levels between 35.0 and 36.5 C. Tympanic temperatures followed rectal temperature values closely but were somewhat higher. In the P-B raft exposure, subject A's body temperature did not stabilize and went below 35 C but, at the same time, tympanic temperatures were recorded as 36 C. A less dramatic, but still significant, trend in body temperature is seen in subject C while in the same raft. The skin temperature changes were more abrupt but the critical regions (hands and feet) still remained well above hazardous levels. Behavioral accommodation accounts for most of this response.

Each subject terminated the TUL raft test at his own request. All had reached subjective tolerance limits that fairly well paralleled their thermal status. The subject dressed in the full pressure suit aborted because of respiratory complications resulting from a problem of suit fit. Upon unzipping the pressure suit, this man cooled very rapidly. In the P-B raft test, an arbitrary time of 6 hours was agreed upon, based primarily on the subject's physiological and psychological status after the first raft exposure. The test monitors also felt that this data-time sample would be sufficient for comparative purposes with the TUL raft exposure.

Water and air temperatures varied from 0 to 2 C and —5 to 4 C respectively. Wave action was recorded as 6

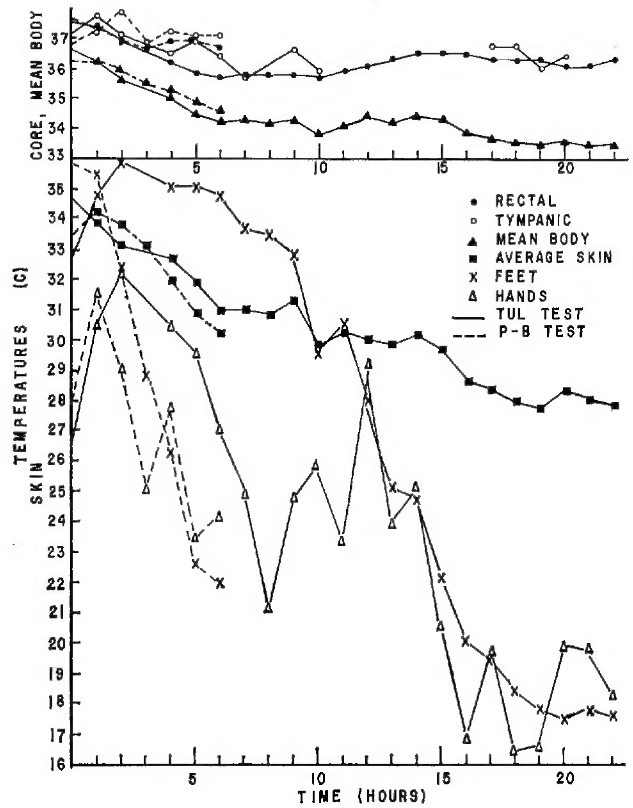

Fig. 8. Comparison of TUL and P-B Rafts (Subject B—Anti-Exposure Suit).

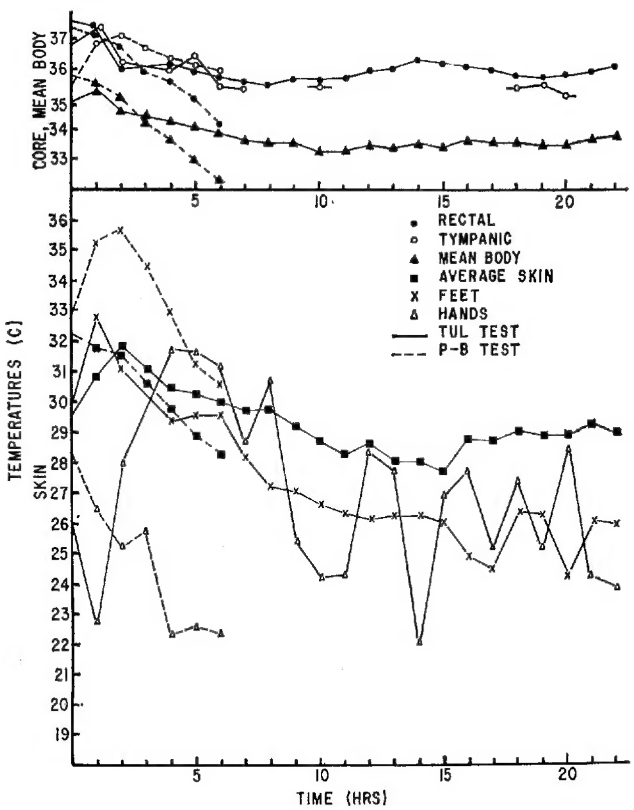

Fig. 7. Comparison of TUL and P-B Rafts (Subject A—NASA Flight Clothing).

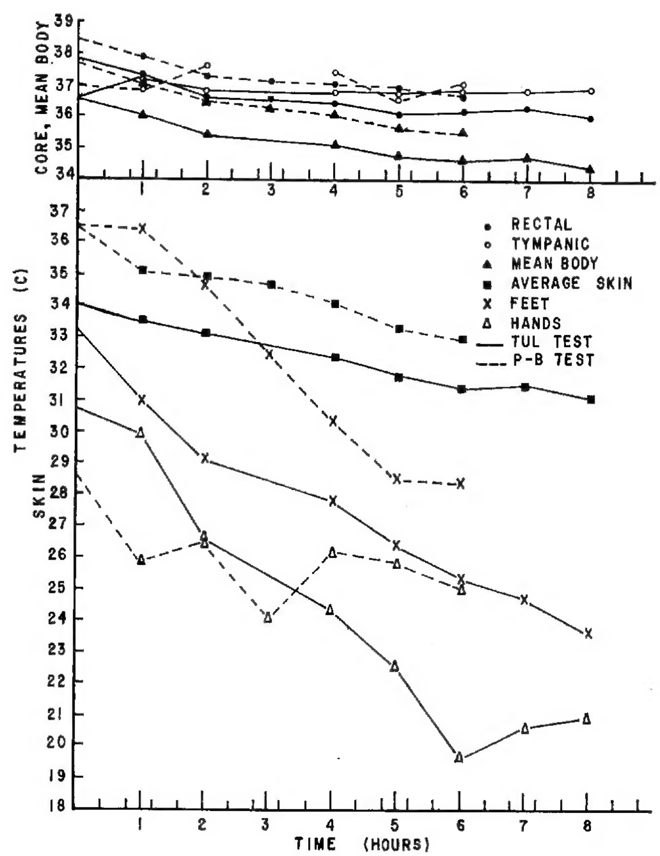

Fig. 9. Comparison of TUL and P-B Rafts (Subject C—Full Pressure Suit).

to 8 feet in the TUL raft exposure and 2 to 6 feet during the test with the P-B raft. Wind velocity varied from 90 to 1,250 feet/minute. Temperatures within the rafts were 4 to 20 C above ambient, depending upon location. All subjects took Tigan® pills to prevent motion sickness. One subject, A, was seasick during the entire test period and vomited repeatedly. All subjects stated they were cold and had long bouts of shivering. Urination was extremely difficult and the subjects dressed in the anti-exposure and full pressure assemblies had to be assisted in moving about or unzipping equipment. The biochemical data obtained from the blood and urine were collected before and after the TUL exposure (Table III). No significant biochemical changes were noted although the weight loss of each subject is of interest.

DISCUSSION

Marked differences were seen between the two rafts and the clothing. All three of the clothing assemblies were inadequate for prolonged periods. The NASA flight clothing does not provide sufficient insulation and, in a drafty raft such as the present P-B design, a person dressed in this clothing would be in serious thermal difficulty within 10 to 15 hours. The reasons the subject endured 22 hours in the TUL raft were because of additional insulation afforded by the cocoon and behavioral factors such as tucking his feet under the other's arms, hands in the groin area, sitting on another subject's coat, and sheer fortitude. The waffle-weave underwear was the crucial clothing in this assembly.

The NASA full pressure suit, if zipped, was thermally adequate for the short exposure times (6 and 8 hours). However, lack of mobility, neck ring discomfort, fatigue factor and thermal problems of the unzipped garment eliminates this clothing configuration except in an emergency. The pressure gloves were unsuitable and provided almost no thermal protection. Also, three men wearing full pressure suits could not fit in the TUL raft. The neck dam, or a suitable substitute, is necessary to prevent frozen condensation on the spray canopy from falling into the suit.

The Air Force ventile assembly is much too bulky and some layers should be removed. Thermally this clothing appears adequate under these conditions, and a person in a survival situation, even in the P-B raft, would probably survive for a period of days. The ventile booties are much too constrictive, however, and should be constructed larger. The ventile hood is of questionable value within an enclosed raft.

All personnel (subjects, monitors) agreed that the TUL raft was superior to the P-B raft. The main assets of the TUL raft were the individual cocoons and the tight spray canopy. The primary liability of the P-B raft was its draftiness as the front curtain did not have a positive seal. No ventilation problems were reported with either raft "buttoned up." Housekeeping is a decided problem. Both rafts had good stability characteristics and rode out the gusty winds and moderate swells very well. The physiological data illustrate these differences between rafts in the marginal case, such as with Subject A.

During this test, the Tigan® pills appeared effective in preventing motion sickness. The present vomitus collection bags were adequate. These same bags can be used for urination. The palatability of the survival food was variable and little or no water was drunk. The dehydration and weight loss did not present any physiologic problems over the 22-hour period. No significant urine or blood chemistry changes were found. In these tests the rectal temperature appears to lack validity as a core temperature measure since that region may become part of the shell as severe cooling occurs. This is verified by the elevated tympanum temperatures of subject A (P-B exposure), subject B (P-B exposure), and subject C (TUL exposure). The evidence is not conclusive, however, and should be verified by further work in order to select the correct criteria in which to evaluate physiological limits under these conditions.

CONCLUSION

The physiologic data and subjective judgments provided valuable insights into the thermal characteristics of a life raft and personal clothing required to ensure long term survival in Arctic waters. These data clearly demonstrated the superior thermal characteristics of one raft construction over another. This study also showed that none of the three clothing assemblies is optimal. The NASA flight clothing is completely inadequate, the NASA FPS marginal at best, and the optimal anti-exposure suit assembly acceptable with many reservations.

ACKNOWLEDGEMENTS

We wish to thank the persons who participated as test subjects or experimental monitors and to acknowledge the support re-

TABLE III. BODY WEIGHTS AND BIOCHEMISTRY, TUL RAFT EXPOSURE

Subject	Date	Time	Subject's Weight (kg)	URINE* pH	Sp. Gr.	Prot.	Sug.	Vol. (cc)	BLOOD HCT**	HGB***
A Pre	3 Feb	1325	73.64	6	1.027	Neg	Neg	70	43	15.1
Post	4 Feb	1545	71.27	6	——	200 mg	Neg	21	45	15.4
B Pre	3 Feb	1300	72.18	6	1.022	Neg	Neg	140	45	15.3
Post	4 Feb	1545	70.81	6	1.022	Neg	Neg	154	44	15.0
C Pre	3 Feb	1330	71.95	7	1.025	Neg	Neg	40	44	15.3
Post	4 Feb	0215	70.81	—	1.019	Trace	Neg	—	45.5	——

*Combistix were used to determine urine specific gravity, sugar and protein.
**Standard centrifuge method.
***Cyanmethemoglobin method.

ceived from the U.S. Navy personnel at Kodiak Naval Station, Alaska. Without their assistance the field test would not have been possible. This research program was conducted jointly by the Aerospace Medical Research Laboratory (AMRL) and the NASA Manned Spacecraft Center, Houston, Texas, and funded under NASA MIPR-T-80489.

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 80-33.

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Medical Factors in Unlimited Class Air Racing Accidents

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Unlimited class air racing for reciprocating engine aircraft consists of both transcontinental and closed course pylon events. Participating aircraft are highly modified World War II fighters capable of speeds approaching 500 mph. Flight environments range from maximum performance on-the-deck continuous high-G pylon turns to unpressurized high altitude trans-continental flight. This paper presents results of investigation of seven fatal crashes involving probable medical factors implicated in this unique type of highly stressful competitive flying, including one case of probable myocardial infarction. The extent to which the effects of sedation, drug and alcohol use, fatigue, and gastrointestinal symptoms may lower the pilot's G tolerance as well as impair his ability to react successfully in an emergency situation, are apparently not well understood by many race pilots. It is concluded that improved education of pilots is necessary in this specialized area of aviation and that there is sufficient evidence to recommend that pilots participating in an unlimited racing event be required to pass a physical examination immediately prior to the race to qualify.

AFTER A LAPSE OF 15 YEARS unlimited class air racing for reciprocating engine aircraft was resumed in 1964, consisting of both transcontinental and closed course pylon racing events. During the past seven years several crashes, some involving pilot fatalities, have occurred in experimental race trials or test flights, and two deaths have been associated with scheduled races. Additional incidents have also occurred which could have resulted in serious consequences to pilots, spectators, and the future of air racing as a sport. The objective of this study has been to examine past associated accidents in this unique type of highly stressful competitive flying to determine what, if any, medical factors might be involved.

BACKGROUND

Although air racing undoubtedly began with the second aeroplane, the first official recorded race was the Gordon Bennett Trophy Race of 1909, which attracted 38 aircraft.[1] On 22 August of that year a red R.E.P. monoplane struggled and sputtered across the muddy field at Bethany, France, but despite roars of encouragement from the crowd of more than 100,000 spectators, it refused to take to the air, much to the disgust of the mud splattered pilot. Three of six events (for $10,500 prize money) involved the fastest speed around one, two, and three laps of a 10-kilometer closed pylon course. Louis Bleriot, who had flown the English channel the previous month, set the first closed course world speed record of 42.87 mph, although Glenn Curtis eventually won the meet with an average speed of 47.65 mph.[2] Bleriot also set the stage for future medical concern when, as the first pilot in the initial qualification trials, his engine failed and he made a dead-stick landing after only one lap (Figure 1). At one point there were 12 crashed aircraft scattered around the aerodome.[3] In 1910 the first air race was held in the United States, speeds had increased to 70 mph, and 37 race pilots were killed (Figure 2). Air racing's popularity reached a peak by 1939 and did much to stimulate new aircraft and engine design. During the post-war years the unlimited races featured "modified" World War II fighters. However, a number of factors contributed to a decline in interest, and after a three-fatality accident in 1949 the unlimited class air races were stopped and not revived until 1964.

The last several post-war races involved a high proportion of accidents.[4] During the 1947 Thompson Trophy Race, for example, out of 13 aircraft lined up for the 20-lap, 300-mile closed course pylon race, seven crashed or made emergency dead-stick landings when overtaxed engines blew up. Only one fatality occurred in this race when an F2G-1 Corsair exploded into the ground at 400 mph approaching a pylon turn. The course was literally strewn with wrecked and burning aircraft. In 1948 7 out of 10 aircraft entered failed to finish, one pilot being penalized for clipping trees although all aircraft were flying below 200 feet altitude. In the last post-war Cleveland race in 1949 8 of 10 unlimited class closed course racers finished. However, Bill Odam overturned pylon No. 2, high-speed stalled, rolled and exploded into a house, killing himself, a mother and her 13-month-old boy. This incident contributed heavily to the subsequent halting of unlimited

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